ATTACHMENT A

PULSTAR REACTOR

ENVIRONMENTAL RADIATION SURVEILLANCE REPORT

FOR THE PERIOD
JANUARY 1, 2018 - DECEMBER 31, 2018

NORTH CAROLINA STATE UNIVERSITY

ENVIRONMENTAL HEALTH AND SAFETY CENTER

RADIATION SAFETY DIVISION

by

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1. INTRODUCTION

The Environmental Radiation Surveillance Program exists to provide routine measurements of the university environment surrounding the PULSTAR Reactor. The specific objectives of this program include:

1) Providing information that assesses the adequacy of the protection of the university community and the public-at-large;

2) Meeting requirements of regulatory agencies;

3) Verifying radionuclide containment in the reactor facility;

4) Meeting legal liability obligations; and

5) Providing public assurance and acceptance.

Table 1
Environmental Monitoring Programs for the PULSTAR Reactor at North Carolina State University

Sample	Activity Measured	Conducted By	Previous Frequency	Current Frequency	Basis For Measurement
Stack Gases	Gross Gamma	N.E.	Continuous	Continuous	10 CFR 20 T.S. 6.7.4
Stack Particles	Gross Beta Gamma Emitters	N.E. N.E.	Monthly	Monthly	10 CFR 20 T.S. 6.7.4
Water from Reactor Facility	Gross Beta Gross Gamma Tritium	N.E. N.E. N.E.	Prior to Discharge (~ Monthly)	Prior to Discharge (~ Monthly)	10 CFR 20 T.S. 6.7.4 City of Raleigh Ordinance
Air Particles at 4 Campus Stations*	Gross Beta Gamma Emitters	RSD RSD	Weekly Weekly	Quarterly Quarterly	10 CFR 20 10 CFR 20
Air Dose at 7 Campus Stations+	OSD Dosimeter	RSD	Quarterly	Quarterly	10 CFR 20
Surface Water Rocky Branch Creek	Gross Beta Gamma Emitters Tritium	RSD RSD N.E.	Quarterly Quarterly ----------	Quarterly Quarterly Quarterly	NCSU NCSU 10 CFR 20
Vegetation NCSU Campus	Gross Beta Gamma	RSD RSD	Semi-annually	Every Other Year	NCSU NCSU
Milk Local Dairy	I-131	RSD	Monthly	Every Other Year	NCSU

Abbreviations Used in Table:
N.E. = Nuclear Engineering/Reactor Facility; RSD = Radiation Safety Division.
*These 4 stations include:
Withers, Daniels, Polk and the Environmental Health & Safety Center.
+These 7 stations include: PULSTAR Reactor and the 4 air sampling stations, North Hall and a control station (EH&S).

2. AIR MONITORING (TABLES 2.1, 2.2, 2.3 and 2.4)

Air monitoring is performed continually for one week during each of four (4) quarters during the year. The data in Table 2.2 are for gross beta activity levels measured during the year. The highest gross beta activity observed was 18.7 fCi/cubic meter at the Environmental Health and Safety Center station during the week of 11/21/2018 to 11/28/2018. The annual campus average value was 12.5 fCi/cubic meter.

Table 2.3 lists LLD values for several gamma emitters which would be indicative of fission product activity. No gamma activity due to any of these radionuclides was detected.

Table 2.4 lists regulatory limits, alert levels, and average background levels for airborne radioactivity.

TABLE 2.1 LOCATION OF AIR MONITORING STATIONS

SITE	DIRECTION[1]	DISTANCE[2] (meters)	ELEVATION[3] (meters)
DANIELS	SOUTHEAST	90	-8
WITHERS	NORTHEAST	82	-6
EH & S CENTER	WEST	1230	-3
NORTH HALL **	NORTHEAST	402	-4
POLK HALL	WEST	100	-7

[1]DIRECTION - DIRECTION FROM REACTOR STACK
[2]DISTANCE - DISTANCE FROM REACTOR STACK
[3]ELEVATION - ELEVATION RELATIVE TO THE TOP OF THE REACTOR STACK
** ONLY DOSIMETER MONITORING

TABLE 2.2 Airborne Gross Beta Activity (fCi/cubic meter ± 2σ)

PERIOD	Polk	Daniels	Withers	EH&S
2018				
03/21-03/28	13.7 ± 1.2	11.3 ± 1.1	10.5 ± 1.1	11.6 ± 1.1
06/21-06/29	7.6 ± 0.8	16.9 ± 1.1	5.3 ± 0.8	18.1 ± 1.2
09/19-09/27	7.0 ± 0.8	6.2 ± 0.8	17.4 ± 1.1	16.6 ± 1.1
11/21-11/28	16.7 ± 1.2	5.7 ± 0.9	16.2 ± 1.2	18.7 ± 1.3

TABLE 2.3 Airborne Gamma Activity LLD Values (fCi/cubic meter)

PERIOD	Co-57	Co-60	Nb-95	Zr-95	Ru-103	Ru-106	Cs-137	Ce-141	Ce-144
2018									
03/21- 03/28	0.21	0.35	0.29	0.47	0.27	2.37	0.26	0.38	1.22
06/21 - 06/29	0.20	0.37	0.28	0.48	0.28	2.48	0.29	0.34	1.28
09/19 - 09/27	0.18	0.35	0.31	0.54	0.33	2.51	0.29	0.43	1.40
11/21 - 11/28	0.17	0.37	0.37	0.50	0.32	2.41	0.29	0.39	1.41

TABLE 2.4 REGULATORY LIMITS, ALERT LEVELS, AND BACKGROUND LEVELS FOR AIRBORNE RADIOACTIVITY (fCi M^{-3}).

NUCLIDE	REGULATORY LIMIT	INVESTIGATION LEVEL	*AVERAGE N.C. BACKGROUND LEVEL
GROSS BETA	1000	500	20
Cs-137	2×10^5	100	2
Ce-134	2×10^5	100	0
Nb-95	2×10^6	100	0
Zr-95	400	100	0

* This data represents an average value measured in North Carolina at various locations. Excerpted from *2009 Environmental Surveillance Report* produced by the NC Department of Health and Human Services Radiation Protection Section.

3. **MILK** (TABLE 3.1)

Milk samples are collected every other year from the Campus Creamery and the Lake Wheeler Road Dairy as processed milk and raw milk and analyzed for I-131. No samples were collected in 2018.

TABLE 3.1 I-131 IN COW′S MILK (pCi Liter^{-1} ± 2 σ) LLD ~ 2 pCi Liter^{-1}

	pCi Liter^{-1}	
DATE	Campus Creamery	Lake Wheeler
2018	No Data	No Data

4. SURFACE WATER (TABLES 4.1 AND 4.2)

Table 4.1 gives the gross alpha and beta activities for water from Rocky Branch at points where it enters (ON), behind Carmichael Gymnasium (GYM) and exits (OFF) the campus. The LLD value for gross alpha and beta activities is ~ 0.4 pCi Liter^{-1}. For gross alpha activity the Investigation Level is 5 pCi Liter^{-1} and the Regulatory Limit is 15 pCi Liter^{-1}. For gross beta activity the Investigation Level is 12.5 pCi Liter^{-1} and the Regulatory Limit is 50 pCi Liter^{-1}. Gamma analysis of all samples was also performed. All the results are consistent with the presence of naturally-occurring radionuclides and none of the gamma emitters listed in Table 4.2 were detected.

TABLE 4.1 GROSS ALPHA AND BETA ACTIVITY IN SURFACE WATER (pCi Liter $^{-1}$ ± 2σ)

LLD_α ~ 0.4 pCi Liter^{-1} LLD_β ~ 0.4 pCi Liter $^{-1}$

		pCi Liter $^{-1}$	
DATE	LOCATION	GROSS ALPHA	GROSS BETA
FIRST QUARTER 2018	ON	0.05 ± 0.2	2.9 ± 0.6
	OFF	0.05 ± 0.2	2.6 ± 0.6
	GYM	0.2 ± 0.2	2.6 ± 0.6
SECOND QUARTER 2018	ON	0.4 ± 0.3	3.3 ± 0.7
	OFF	-0.1 ± 0.2	0.1 ± 0.5
	GYM	0.5 ± 0.3	3.8 ± 0.7
THIRD QUARTER 2018	ON	0.2 ± 0.2	5.6 ± 0.8
	OFF	0.1 ± 0.2	4.8 ± 0.7
	GYM	0.0 ± 0.1	7.6 ± 0.9
FOURTH QUARTER 2018	ON	0.3 ± 0.3	3.1 ± 0.7
	OFF	0.1 ± 0.3	1.7 ± 0.6
	GYM	0.4 ± 0.3	3.7 ± 0.7

TABLE 4.2 LLD VALUES FOR GAMMA EMITTERS IN SURFACE WATER

NUCLIDE	LLD (pCi Liter^{-1})
Co-60	0.4
Zn-65	0.7
Cs-137	0.3
Cs-134	0.4
Sr-85	0.4
Ru-103	0.3
Ru-106	3.0
Nb-95	0.4
Zr-95	0.5

5. VEGETATION (TABLE 5.1 & 5.2)

Tables 5.1 gives gross beta activities for grass samples collected on the NCSU Campus. Table 5.2 lists LLD values for several gamma emitters. No samples were collected in 2018. The vegetation sampling is performed every other year.

TABLE 5.1 GROSS BETA ACTIVITY IN CAMPUS VEGETATION * LLD – 0.5 pCi g^{-1}

SAMPLE DATE	SAMPLE LOCATION	(pCi $g^{-1} \pm 2\sigma$)
2018	NORTH CAMPUS	No Data
2018	SOUTH CAMPUS	No Data
2018	EAST CAMPUS	No Data
2018	WEST CAMPUS	No Data

TABLE 5.2 LLD VALUES FOR GAMMA EMITTERS IN VEGETATION

NUCLIDE	LLD (pCi $gram^{-1}$)
Co-60	0.01
Zn-65	0.02
Cs-137	0.01
Cs-134	0.01
Sr-85	0.01
Ru-103	0.01
Nb-95	0.01
Zr-95	0.02

6. OPTICALLY STIMULATED DOSIMETERS (TABLE 6.1)

Dosimeter analysis is contracted to Landauer, Inc. for determination of ambient radiation exposures. Exposures are integrated over a three-month period at each of the air monitor stations listed in Table 2.1 and at the PULSTAR Reactor facility. A control dosimeter is located in the Environmental Health & Safety Center. Table 6.1 gives the dose equivalent data for these eight (8) locations.
The dose equivalents are reported as millirem per quarter year. Readings which fall below the dosimeters' minimum measurable quantities (i.e., 1 millirem for gamma radiations and 10 millirem for beta radiation) are reported by the contract vendor with the designation **"M"**. The observed readings are typically within the expected range for natural background radiation levels.

TABLE 6.1 ENVIRONMENTAL DOSIMETER DOSES - Millirem per Quarter

Period	**Control**	Polk	Withers	Daniels	EHS	North	PULSTAR
2018							
01/01-03/31	51	**M,M**	**M,M**	**M,M**	**M**	**M**	15
04/01-06/30	48	**M,M**	**M,M**	**M,M**	**M**	**M**	9
07/01-09/30	54	**M,M**	**M,M**	**M,M**	**M**	**M**	3
10/01-12/31	54	**M,M**	**M,M**	**M,M**	**M**	**M**	6

7. QUALITY CONTROL INTERCOMPARISON PROGRAM

The Environmental Radiation Surveillance Laboratory (ERSL) in the Radiation Safety Division has analyzed samples provided by the U.S. DOE Mixed-Analyte Performance Evaluation Program (MAPEP Test Session 39) Radiological and Environmental Sciences Laboratory (RESL) during this reporting period. The objective of this program is to provide laboratories performing environmental radiation measurements with unknowns to test their analytical techniques. Due to DOE/MAPEP funding issues, cross-check test samples are currently not being supplied for gross alpha/beta water and gross alpha/beta air filter analyses.

The MAPEP value listed in the Tables 7.1 (a-c) to which the ERSL results are compared is the mean of replicate determinations for each nuclide. The MAPEP uncertainty is the standard error of the mean.

For each reported radiological analyte, the laboratory result and the reference value may be used to calculate a relative bias:

$$\%\text{Bias} = \frac{(100)(\text{Laboratory Result} - \text{RESL Reference Value})}{\text{RESL Reference Value}}$$

The relative bias will place the laboratory result in one of three categories:

Acceptable…… Bias $\leq$ 20%
Acceptable with Warning... 20% < Bias $\leq$ 30%
Not Acceptable…….… Bias > 30%

TABLE 7.1a

MULTINUCLIDE WATER SAMPLE - INTERCOMPARISON STUDY
01 August 2018

The sample consists of a spiked aliquot of acidified water (~5 % HNO_3). The reported values and the known values are given in Bq/Liter.

	***NCSU - ENVIRONMENTAL LABORATORY RESULTS**			
Radionuclide	***Reported Value**	***Reported Error**	**MAPEP Value**	**Acceptance Range**
Co60	**0.8**	**1.0**	**--------**	**False + Test**
Cs137	**6.99**	**0.87**	**6.9**	**4.8 – 9.0**
Cs134	**9.63**	**0.58**	**8.7**	**6.1 – 11.3**
Co57	**15.28**	**0.37**	**14.9**	**10.4 – 19.4**
Mn54	**12.61**	**0.49**	**12.5**	**8.8 – 16.3**
Zn65	**8.10**	**0.74**	**7.53**	**5.27 – 9.79**

Note: The entry "------"indicates no analyte was present for purposes of conducting a False Positive (+) Test.

TABLE 7.1b

MULTINUCLIDE AIR FILTER - INTERCOMPARISON STUDY
01 August 2018

The sample consists of one 50 mm diameter glass fiber filter which has been spiked with a solution and dried. The reported values and the known values are given in Bq/filter.

***NCSU - ENVIRONMENTAL LABORATORY RESULTS**

Radionuclide	*Reported Value	*Reported Error	MAPEP Value	Acceptance Range
Co60	0.32	0.05	0.294	0.206 - 0.382
Cs137	0.37	0.05	0.345	0.242 - 0.449
Cs134	0.48	0.04	0.444	0.311 - 0.577
Co57	0.58	0.04	0.592	0.414 - 0.770
Mn54	0.29	0.05	0.266	0.186 - 0.346
Zn65	0.17	0.07	0.201	Sensitivity Evaluation

Note: The entry "------"indicates no analyte was present for purposes of conducting a False Positive (+) Test.

TABLE 7.1c

MULTINUCLIDE VEGETATION SAMPLE - INTERCOMPARISON STUDY
01 August 2018

The sample consists of a spiked sample of vegetation. The reported values and the known values are given in Bq/sample.

***NCSU - ENVIRONMENTAL LABORATORY RESULTS**

Radionuclide	*Reported Value	*Reported Error	MAPEP Value	Acceptance Range
Co60	2.04	0.11	1.68	1.18 - 2.18
Cs137	2.78	0.13	2.36	1.65 - 3.07
Cs134	2.21	0.11	1.94	1.36 - 2.52
Co57	3.97	0.10	3.31	2.32 - 4.30
Mn54	3.30	0.08	2.53	1.77 - 3.29
Zn65	0.79	0.10	1.37	0.96 - 1.78

Note: The entry "------" indicates no analyte was present for purposes of conducting a False Positive (+) Test.

8. CONCLUSIONS

The data obtained during this period do not show any fission product activities. The observed environmental radioactivity is due primarily to radon progeny, primordial radionuclides (e.g. K-40) and those radionuclides which originate in the upper atmosphere as the result of cosmic ray interactions. These facts justify the conclusion that the PULSTAR Reactor facility continues to operate safely and does not release fission product materials into the environment.